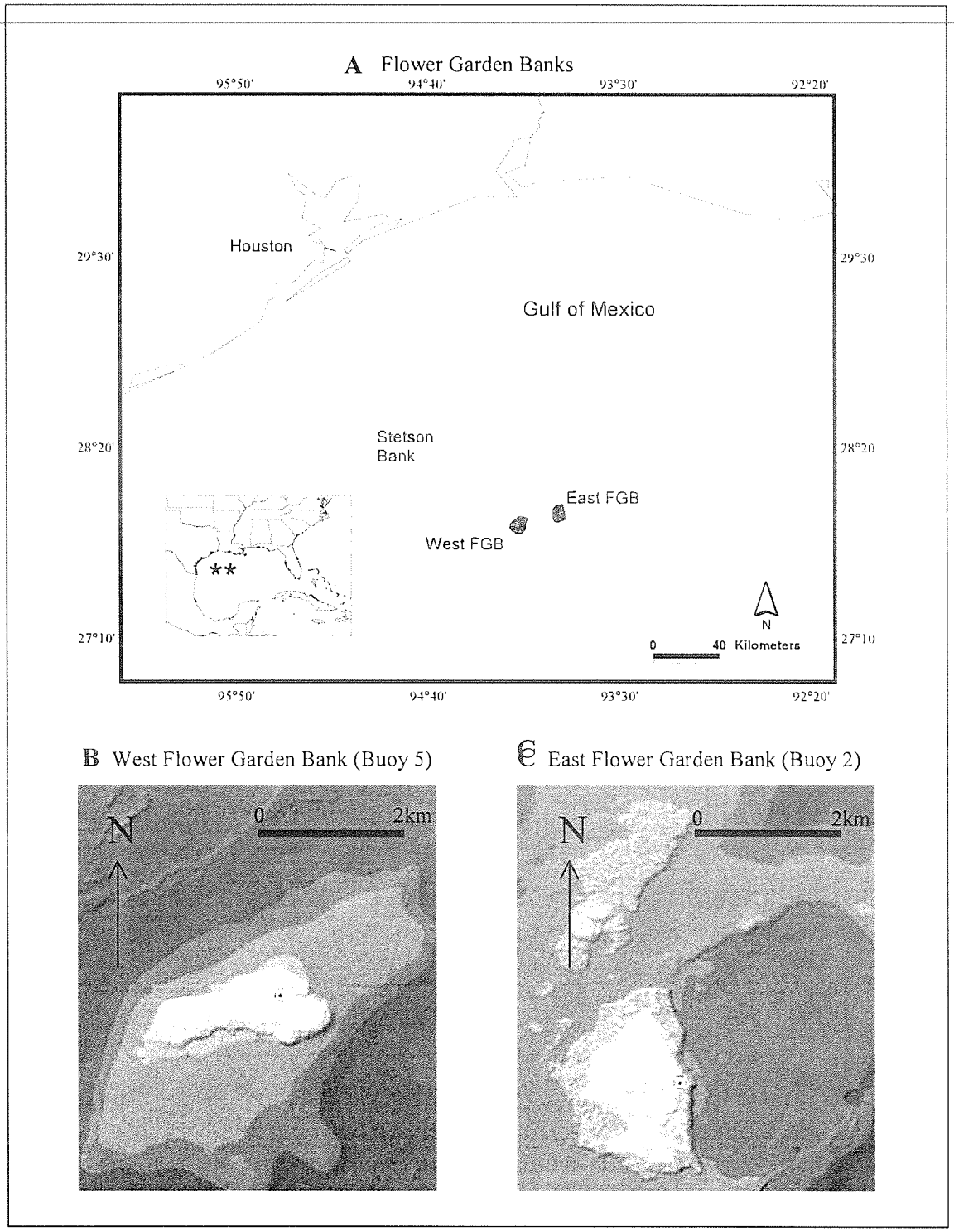

Figure 1. (**A**) AGRRA survey sites at the Flower Garden Banks. Location of (**B**) Buoy 5, West Flower Garden, (**C**) Buoy 2, East Flower Garden Bank. ⊡=Buoy

A RAPID ASSESSMENT OF THE FLOWER GARDEN BANKS NATIONAL MARINE SANCTUARY (STONY CORALS, ALGAE AND FISHES)

BY

CHRISTY V. PATTENGILL-SEMMENS[1] AND STEPHEN R. GITTINGS[2]

ABSTRACT

Benthic and fish communities at one site on each of the East and West Flower Garden Banks were assessed using the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol in August 1999. Surveys at 20-28 m revealed high coral cover (~50%) dominated by large (mean diameter 81-93 cm) healthy corals with total (recent + old) partial-colony mortality values averaging 13%. Turf algae were the dominant algal functional group and the mean relative abundance of macroalgae was <10%. The large abundance, size and biomass of many fishes reflected the low fishing pressure on the Banks. Due to their near-pristine condition, the Flower Garden Banks data will prove to be a valuable component in the rapid assessment database and its resulting determination of regional reef condition.

INTRODUCTION

The East and West Flower Garden Banks (EFG and WFG), located 175 km southeast of Galveston, Texas on the edge of the U.S. Gulf Coast continental shelf (Fig. 1A), were created by the uplift of Jurassic-age salt domes. Rising about 100 m above the surrounding depths to within 18 m of the surface, the Flower Garden Banks (FGB) support the northernmost coral reefs in the continental United States. The low diversity (about 21 species), high cover and large size of stony corals, and the low abundance of benthic macroalgae relative to most Caribbean reefs have been well documented (Bright and Pequegnat, 1974; Bright et al., 1974; Boland et al., 1983; Dennis, 1985; Rezak et al., 1985; Dennis and Bright, 1988; Gittings et al., 1993). The FGB are also less susceptible to bleaching than most coral reefs because they are fairly deep; the 1998 regional mass bleaching event did not occur here. The FGB are dominated by massive boulder corals (particularly *Montastraea* spp. and *Diploria* spp.) but lack acroporids and shallow-water gorgonians.

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Fish diversity is also comparatively low (approximately 260 species) but abundances are high (Pattengill, 1998). Fish families and groups that are notably absent, or only represented by one or few species, include grunts (Haemulidae), snappers (Lutjanidae), and hamlets (*Hypoplectrus* sp.). The Banks are year-round habitat for manta rays (*Manta birostris* and *Mobula hypostoma*) and whale sharks (*Rhincodon typus*) and serve as a winter habitat for several species of schooling sharks including scalloped hammerheads (*Sphyrna lewini*), silky sharks (*Carcharhinus falciformis*), and spotted eagle rays (*Aetobatus narinari*) (Childs, 2001).

A unique feature of the EFG is a brine seep at 72 m. The seep features a brine pool with a chemosynthetic bacterial assemblage that is known to be a significant exporter of carbon to the deeper parts of the Bank (Rezak et al., 1985). The seep also plays a significant role in the physiographic structure of the EFG due to the dissolution of salt which results in local faulting and subsidence.

The EFG and WFG are managed and protected by the National Oceanic and Atmospheric Administration (NOAA)'s National Marine Sanctuary System and the Department of Interior's Minerals Management Service. Together with Stetson Bank, they make up the Flower Garden Banks National Marine Sanctuary (FGBNMS). Anthropogenic impacts on the Flower Gardens are relatively low, mainly due to their distance from land. Very little fishing pressure exists on the reefs (see http://www.sanctuaries.nos.noaa.gov/oms/pdfs/FlowerGardensRegs.pdf; Subpart L or 15CFR922.122); spearfishing and techniques that disturb benthic habitats, including trawls, traps, and bottom long lines, are prohibited but hook-and-line fishing is permitted. The main, local source of human-induced disturbance is mechanical damage due to anchors, seismic cables, and occasionally long-line fishing tackle. Scuba diving is allowed on the Banks and moorings have been installed to reduce anchor damage. A long-term monitoring program has been in place for approximately 20 years. Historical biotic changes have been attributed primarily to regional or global events such as the die-off of *Diadema antillarum* and periodic coral bleaching.

In August 1999, an AGRRA expedition to the FGB was coordinated by NOAA and the Reef Environmental Education Foundation (REEF) in conjunction with the annual FGBNMS REEF Field Survey for volunteer fish monitoring. The Banks were chosen for the survey because "end-member" reefs, including those that are unusually luxuriant, are particularly relevant to the AGRRA program (R. Ginsburg, personal communication).

METHODS

The survey team included seven scientists from the National Marine Sanctuary Program and three REEF experts. NOAA's two long-term monitoring sites at EFG Buoy 2 and WFG Buoy 5 (Fig. 1B, C) each of which is considered representative of the high-diversity stony coral zone on the Bank (Gittings et al., 1992), were strategically chosen for the surveys. The AGRRA protocol version 2.1 (see Appendix One, this volume) was used with the following modifications. Benthic and fish surveys were conducted simultaneously with divers dispersed over a radius of about 150 m around the moored

boat. Five divers conducted coral transects and algal quadrats during any given dive. Coral sizes were measured to the closest 5 cm, and any sediment deposited in the algal quadrats was gently removed by hand waving before estimating the relative abundance of crustose coralline algae. Cyanobacteria were counted as turf algae in 64 quadrats and as macroalgae in three quadrats at EFG. Three divers conducted the fish-belt transects and roving diver (RDT) surveys. Counts of serranids (groupers) were restricted to species of *Epinephelus* and *Mycteroperca*; scarids (parrotfishes) and haemulids (grunts) less than 5 cm in length were not tallied. All surveys were made between depths of 20 and 28m during daylight hours (7:00 a.m.-6:00 p.m.).

The benthic- and fish-transect data were entered into a custom Excel spreadsheet provided by the AGRRA organizing committee. REEF provided the RDT data in the American Standard Code for Information Interchange (ASCII) format. The percent coral cover, percent mortality, mean colony size, incidence of disease and bleaching, and relative algal abundance were calculated and compared between Banks using a t-test. A macroalgal index (calculated as macroalgal index = % relative macroalgal abundance x canopy height–a proxy for macroalgal biomass) was also used as a comparison metric. Using the fish transects as replicates, the average density (#/100 m^2) and size (cm) of each fish species and family recorded were calculated for each site. The average density and size of each species and family were compared between Banks using a t-test. Transect data were also used to calculate biomass for each fish species using standardized conversion equations (Appendix Two, this volume). The RDT survey data provided a species list, frequency of occurrence, and relative abundance data for each Bank. Percent sighting frequency (%SF) for each species was the percentage of dives in which the species was recorded. An estimate of abundance (den) was calculated as: Density score = $((n_S x1)+(n_F x2)+(n_M x3)+(n_A x4)) / (n_S + n_F + n_M + n_A)$, where n_S, n_F, n_M, and n_A represented the number of times each abundance category (single, few, many, abundant) was assigned for a given species.

RESULTS

Due to the minimum depth of the Banks, only one depth interval at each site was surveyed. At the WFG, 135 coral colonies and 55 algal quadrats were examined along 11 benthic transects and 11 RDT fish surveys and 12 fish-belt transects were performed. At the EFG, 160 coral colonies and 67 algal quadrats were surveyed on 14 transects and 15 RDT fish surveys and 12 fish-belt transects were conducted.

Stony Corals

Live stony coral cover averaged 54% and 49% at the WFG and EFG, respectively (Table 1). Nine species of "large" stony corals (with diameters ≥25 cm) were recorded within the transects at the WFG and 11 species at the EFG. Dominant species at the WFG (Fig. 2A) were *Montastraea franksi* (40% of all colonies counted), *Diploria strigosa* (27%), *Montastraea cavernosa* (8%), and *Montastraea faveolata* (7%). The dominant

corals at the EFG (Fig. 2B) were *Montastraea franksi* (37%), *Porites astreoides* (16%), *Montastraea cavernosa* (13%), and *Diploria strigosa* (13%).

The average diameter of the large corals (Table 2) was significantly greater (t-test; $P<0.05$) at the WFG than at the EFG (93 versus 81 cm, respectively). None of the transected corals showed any signs of disease. Parrotfish bites were reported in about 8% of all colonies surveyed. Pale bleaching was noted in some colonies (~6-16%). Overall, for colony surfaces recent mortality averaged 2%, mean old mortality was 11.5% and total partial mortality averaged 13%.

The density of coral recruits found in the quadrats was 2.3 and 1.7 per m^2 at the WFG and EFG, respectively (Table 3). The recruits were *P. astreoides* and *Agaricia agaricites*, in equal proportions.

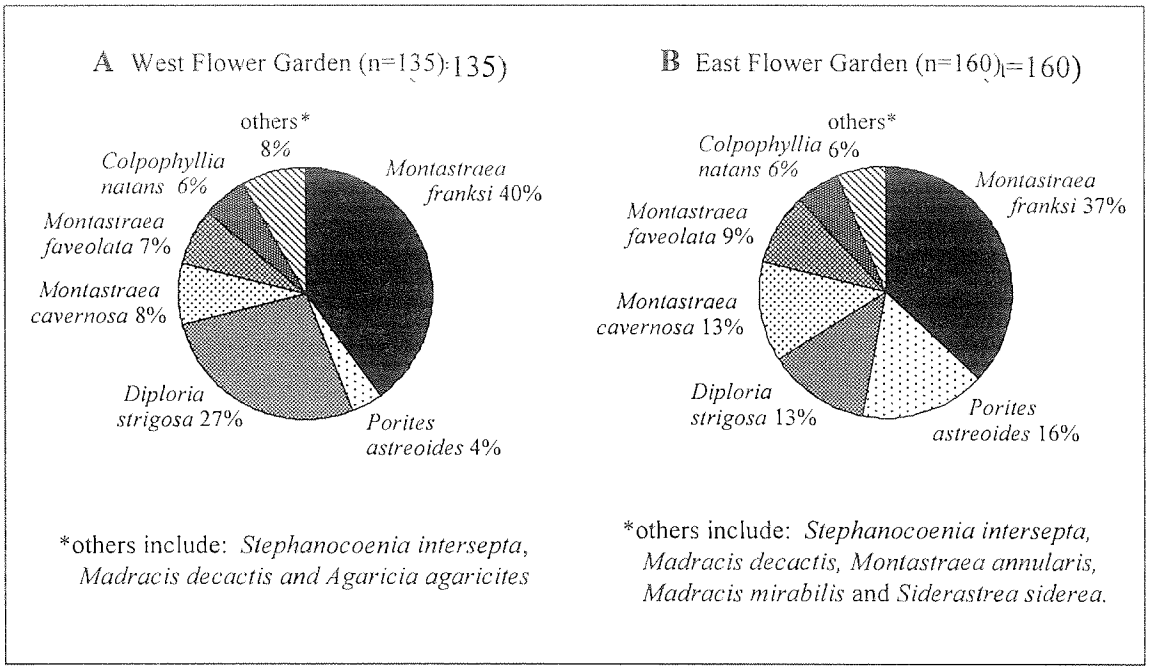

Figure 2. Species composition and mean relative abundance of all stony corals (≥25 cm diameter) at (**A**) West Flower Garden, (**B**) East Flower Garden Bank reefs.

Algae

Relative macroalgal abundance was very low (<10%) on both Banks (Table 3). Average macroalgal height was 1.0 cm, yielding macroalgal indices of 8.0 and 10.0 at the WFG and EFG, respectively. A mat cyanobacterium at the EFG that was common in the algal quadrats, on the sand flats, and on several coral heads was most likely responsible for the significantly higher (80% versus 72%) relative abundance values of turf algae at the EFG (t-test; $p<0.05$). Very few individuals of *Diadema antillarum* were sighted within the transects (0.9 and 1.4/100 m^2 at the WFG and EFG, respectively).

Fish

The average density of most families (Fig. 3) and species of fishes surveyed in the belt transects was similar at the EFG and WFG. Parrotfish were the most abundant fish recorded in the transects. The densities of graysby (*Epinephelus cruentatus*) and Spanish hogfish (*Bodianus rufus*) at the WFG were approximately twice those at the EFG (t-test; $p<0.05$). The density of reef butterflyfish (*Chaetodon sedentarius*) was also two and a half times greater at the WFG; however, this difference was not significant (t-test; $p=0.059$). Grunts, several species of parrotfish and snapper, hogfish (*Lachnolaimus maximus*), and gray angelfish (*Pomacanthus arcuatus*) were absent at both Banks, a distinguishing characteristic of the FGB's fish assemblage (Pattengill, 1998).

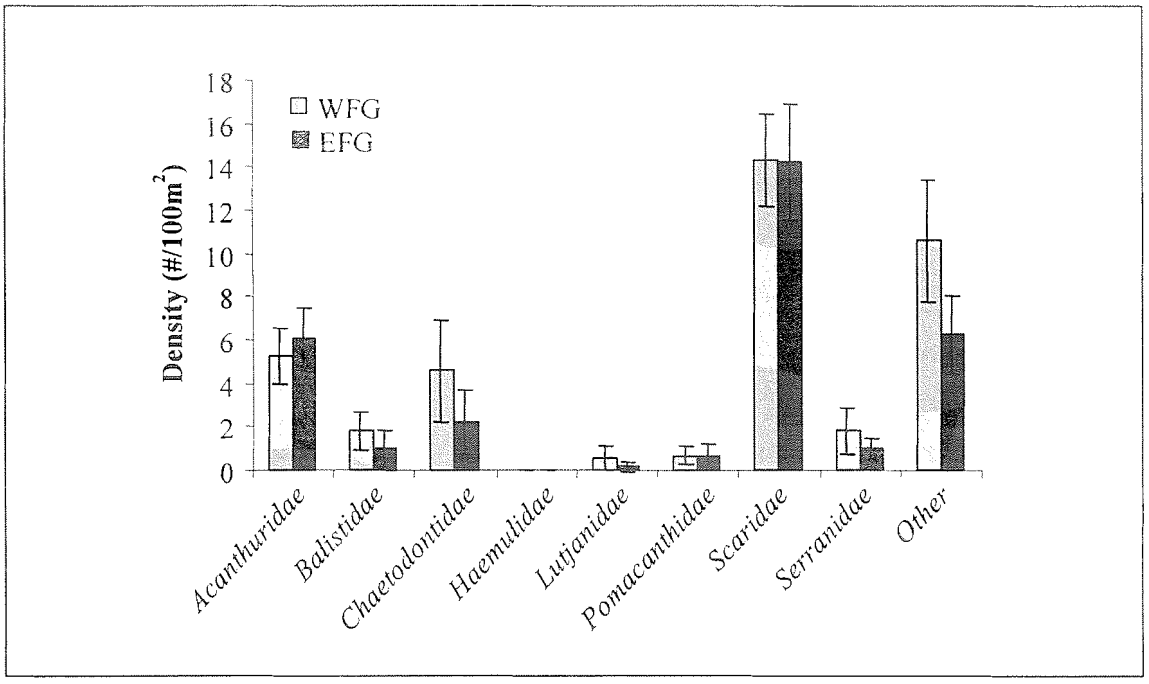

Figure 3. Mean fish density (no. individuals/100 m^2 ± sd) for eight fish families at the WFG (West Flower Garden) and EFG (East Flower Garden) Banks. Other = *Bodianus rufus, Caranx ruber, Lachnolaimus maximus, Microspathodon chrysurus, Sphyraena barracuda.*

A total of 117 fish species were seen by the AGRRA team during RDT surveys at the EFG and WFG. Great barracuda (*Sphyraena barracuda*), sharpnose puffer (*Canthigaster rostrata*), and black durgon (*Melichthys niger*) were documented in all surveys (Table 4). Species that were relatively common at the FGB compared to most other Caribbean reefs include longsnout butterflyfish (*Chaetodon aculeatus*), blue angelfish (*Holacanthus bermudensis*), and several species of jacks (Carangidae). Individuals of the golden phase of the smooth trunkfish (*Lactophrys triqueter*), a phase that is unique to the FGBNMS (Pattengill-Semmens, 1999), were also sighted. One new record for the Banks, a sharptail eel (*Myrichthys breviceps*), was recorded at the WFG. (An individual of the same eel species had been recorded on video earlier in the summer.)

Numerically, the most abundant species were: bluehead wrasse (*Thalassoma bifasciatum*), threespot damselfish (*Stegastes planifrons*), bicolor damselfish (*S. partitus*) queen parrotfish (*Scarus vetula*), along with planktivorous creolefish (*Paranthias furcifer*) and brown chromis (*Chromis multilineata*).

Average sizes of parrotfishes and groupers were relatively high which resulted in relatively high biomass values (Table 5). The size frequency distributions of two feeding guilds, carnivores (select grouper genera and snappers) and herbivores (parrotfishes ≥5 cm, surgeonfish, and yellowtail damselfish, *Microspathodon chrysurus*), are shown in figure 4. Three-fourths of the individuals in the carnivore feeding guild were groupers (yellowmouth grouper, *Mycteroperca interstitialis;* tiger grouper, *M. tigris*; graysby, *E. cruentatus*; coney, *E. fulvus*; in descending order of density) with gray snapper (*Lutjanus griseus*) making up the remainder. Approximately 45% of these carnivores were greater than 30 cm in length (Fig. 4A) and the average size of the groupers was 25 cm. Approximately 70% of the individuals in the herbivore feeding guild were between 11 and 30 cm (Fig. 4B). The average size of the parrotfishes was 22 cm.

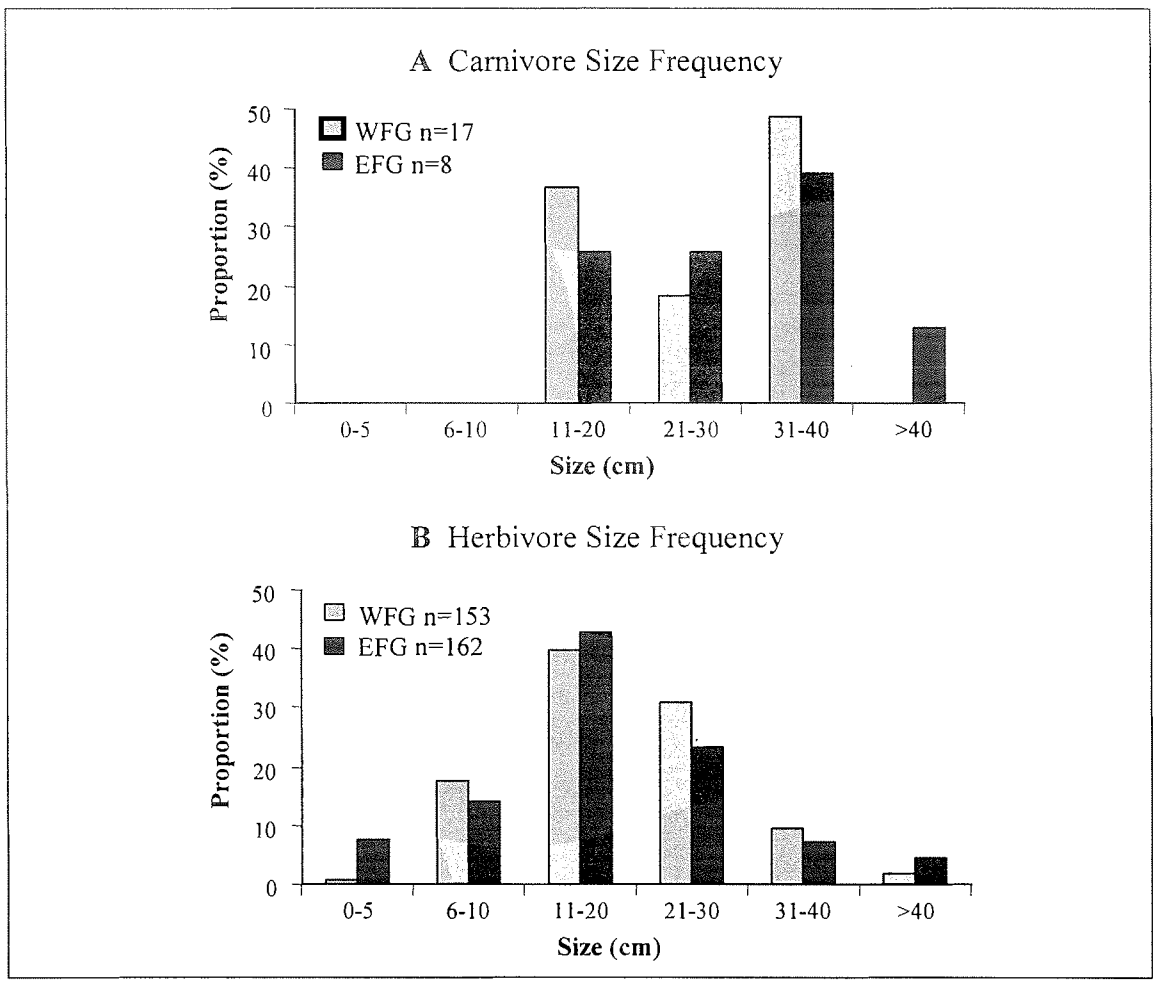

Figure 4. Size frequency distribution of (**A**) carnivores (lutjanids, select serranids) and (**B**) herbivores (acanthurids, scarids ≥5 cm, *Microspathodon chrysurus*) at the WFG (West Flower Garden) and EFG (East Flower Garden) Banks.

For most species, average sizes recorded in the belt transects were similar between the EFG and WFG. Significant differences in length were detected by a t-test in the blue tang (*Acanthurus coeruleus*), which was longer at the WFG, whereas princess parrotfish *(Scarus taeniopterus*) and yellowtail damselfish were longer at the EFG.

DISCUSSION

Results from this assessment revealed reefs with high stony coral cover that are dominated by large boulder corals. Pale bleaching was evident in some surveyed colonies but very little disease was noted and only on stony corals outside the benthic transects. Macroalgal biomass was very low. Results of the fish surveys showed an assemblage that is relatively low in diversity but high in biomass. The Banks appeared to support fewer, but larger, individual fishes in comparison to other Caribbean-area reefs. The large average size of parrotfishes and groupers likely reflected the low fishing pressure on the reefs. Recruitment success appeared to be driving the size differences for three of the surveyed fishes, giving a high abundance of juvenile blue tang on the EFG and a high number of juvenile princess parrotfish and yellowtail damselfish on the WFG.

An additional 15 REEF volunteers conducted 74 RDT surveys during the cruise. These data were not included in the AGRRA data set but were added to the REEF database, which can be accessed from the REEF Website (http://www.reef.org). As a result of annual field surveys at the Banks between 1993 and 1999, a total of 1,495 REEF surveys have been generated for the FGBNMS (over 1,100 survey hours). These data represent a valuable source of information for the Sanctuary management. To date, 257 fish species have been documented at the FGBNMS. A comprehensive fish species list for the FGB has been published using these data (Pattengill, 1998).

The FGB are deep reefs on offshore banks that are far removed from land and experience little anthropogenic disturbance. Described as "near pristine," they provide an important piece of the regional picture of Mesoamerican reef condition. The reefs of the FGB have been, and continue to be, well studied. A long-term monitoring project has been in place for over 20 years. Data collected during the AGRRA assessment corroborated findings of previous studies on the condition of the FGB ecosystem. The importance of these data will be further highlighted when comparable data from dozens of sites are compiled to create a more complete picture of the current status of western Atlantic coral reefs. The FGB can then be used to help "calibrate" the AGRRA "scale" of reef condition.

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Table 1. Site information for AGRRA stony coral, algae and fish surveys on the Flower Garden Banks.

Site name/ buoy #c	Reef type	Latitude (° ' N)	Longitude (° ' W)	Survey date	Depth (m)	Benthic transects (#)	≥25 cm stony corals (#/10 m)	% live stony coral cover (mean ± sd)	30 m fish transects (#)	RDT fish species (#)[1]
WFG #5	bank	27 55.30	93 48.54	August 16 99	22.5	11	12.5	54.0 ± 16.5	12	117
EFG #2	bank	27 54.32	93 35.49	August 18 99	19.5	14	11.5	49.0 ± 6.0	12	117

[1]Species number value at each bank is based on Roving Diver Technique (RDT) surveys.

Table 2. Size and condition (mean ± standard deviation) of all stony corals (≥25 cm diameter), by site on the Flower Garden Banks.

Site name/ buoy #	Stony corals			Partial-colony surface mortality (%)			Corals (%)			
	(#)	Diameter (cm)	Height (cm)	Recent	Old	Total	Standing dead	Bleached[1]	Diseased	with Damselfish bites
WFG #5	135	93.0 ± 72.0	36.0 ± 41.5	1.5 ± 4.0	12.0 ± 21.0	13.5 ± 20.5	1.5	5.5	0	8
EFG #2	160	81.0 ± 53.0	32.5 ± 26.5	2.0 ± 7.0	10.5 ± 19.0	12.5 ± 20.5	2.0	16.5	0	7.5

[1]Includes all colonies with any level (pale, white, etc.) and amount (partial, complete) of bleaching.

Table 3. Algal characteristics, abundance of stony coral recruits and *Diadema antillarum* (mean ± standard deviation), by site on the Flower Garden Banks.

Site Name/ buoy #s	Quadrats (#)	Relative abundance (%)			Macroalgal height (cm)	Macroalgal Index[2]	Recruits (#/.0625 m^2)	*Diadema* (#/100 m^2)
		Macroalgae	Turf algae[1]	Crustose coralline alage				
WFG #5	55	9.0 ± 17.0	71.5 ± 28.5	19.5 ± 28.0	0.9 ± 0.3	8	0.15	0.9
EFG #2	67	9.0 ± 16.5	79.5 ± 22.0	11.0 ± 12.5	1.1 ± 0.5	10	0.10	1.4

[1]Includes cyanobacterial mats

[2]Macroalgal index is relative macroalgal abundance x macroalgal height

Table 4. Twenty-five most frequently sighted fish taxa on the Flower Garden Banks. Data were calculated from RDT surveys conducted during the assessment.

Scientific name	Common name	Sighting frequency (%)	Density score[1]
Sphyraena barracuda	Great Barracuda	100	2.8
Canthigaster rostrata	Sharpnose Puffer	100	2.7
Melichthys niger	Black Durgon	100	2.4
Chaetodon sedentarius	Reef Butterflyfish	96	2.2
Microspathodon chrysurus	Yellowtail Damselfish	96	1.9
Mulloidichthys martinicus	Yellow Goatfish	96	2.6
Epinephelus cruentatus	Graysby	96	1.8
Scarus vetula	Queen Parrotfish	96	3.0
Sparisoma viride	Stoplight Parrotfish	96	2.7
Acanthurus coeruleus	Blue Tang	96	2.3
Lactophrys triqueter	Smooth Trunkfish	92.5	1.8
Stegastes planifrons	Threespot Damselfish	92.5	3.2
Clepticus parrae	Creole Wrasse	92.5	2.8
Kyphosus sectatrix/incisor	Bermuda Chub/Yellow Chub	87.5	2.9
Chromis multilineata	Brown Chromis	84.5	3.5
Stegastes partitus	Bicolor Damselfish	84.5	3.1
Bodianus rufus	Spanish Hogfish	84.5	2.8
Thalassoma bifasciatum	Bluehead	84.5	3.6
Scarus taeniopterus	Princess Parrotfish	84	2.7
Cantherhines pullus	Orangespotted Filefish	80	1.6
Paranthias furcifer	Creole-fish	80	3.8
Halichoeres garnoti	Yellowhead Wrasse	77	2.3
Holacanthus tricolor	Rock Beauty	76	1.7
Acanthurus bahianus	Ocean Surgeonfish	73	2.5
Chromis cyanea	Blue Chromis	72.5	2.3

[1]See Methods for definition of density score.

Table 5. Biomass (mean ± standard deviation) for AGRRA fishes, by site in the Flower Garden Banks.

Site name	Biomass (g/100 m^2)				
	Herbivores		Carnivores		
	Acanthuridae	Scaridae (≥5 cm)	Haemulidae (≥5 cm)	Lutjanidae	Serranidae[1]
WFG #5	960.4 ± 864.5	4263.1 ± 2984.0	0	376.9 ± 736.5	554.3 ± 1041.3
EFG #2	493.2 ± 370.3	4765.2 ± 3387.6	0	252.8 ± 875.6	343.4 ± 473.0

[1]*Epinephelus* spp. and *Mycteroperca* spp.

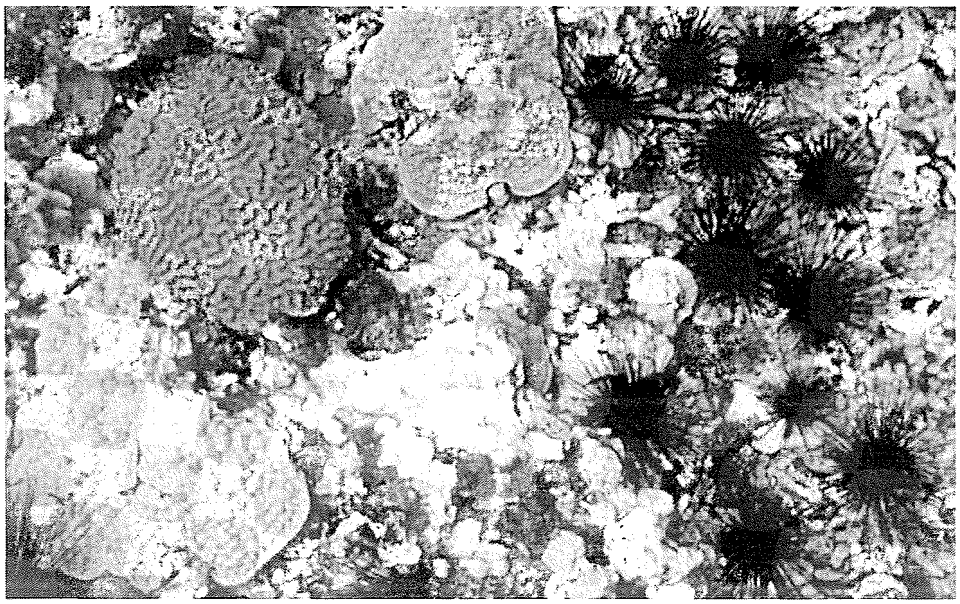

Plate 12A. The formerly ubiquitous, herbivorous sea urchin, *Diadema antillarum*, played a key role in preventing overgrowth of stony corals by macroalgae in many areas of the wider Caribbean prior to its regionwide demise in 1983-1984. Localized population increases are currently being reported, although densities everywhere are still far below pre-dieoff levels. (Photo Andrew W. Bruckner)

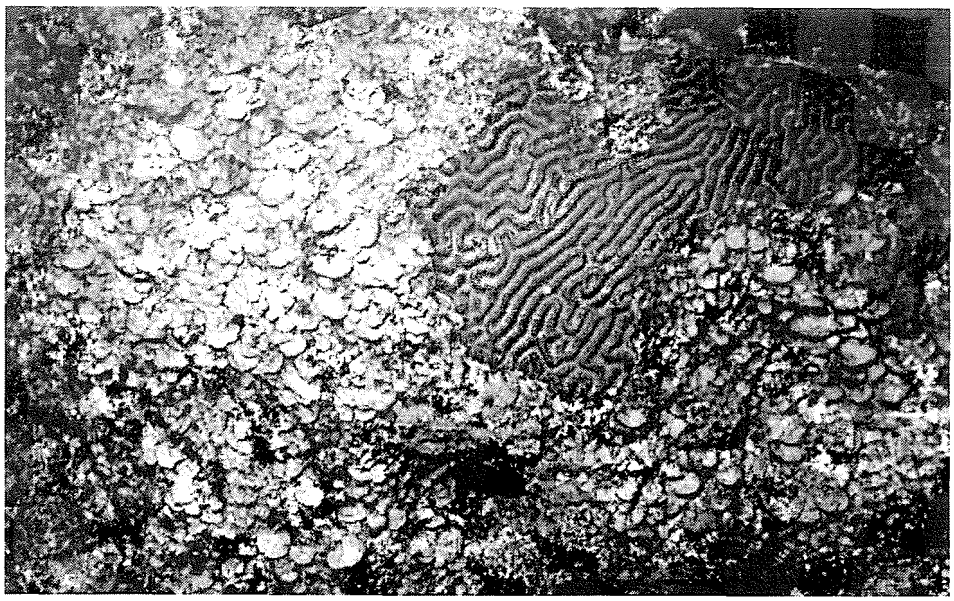

Plate 12B. On many Caribbean reefs lacking large sized herbivorous fishes, the loss of *D. antillarum* has allowed macroalgae to colonize coral skeletons and then overgrow the living coral tissues, as shown for the *Lobophora variegata* on this *Colpophyllia natans*. The result has been a shift to algal dominated reefs in some areas, as well as increased mortality and reduced recruitment of stony corals. (Photo Andrew W. Bruckner)